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(54) **METHOD OF MANUFACTURING ELECTRODE COMPLEX FOR FORMING ELECTRODE OF SPARK PLUG, AND METHOD OF MANUFACTURING SPARK PLUG**

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H01T 21/02 (2006.01)
H01T 13/32 (2006.01)
H01T 21/06 (2006.01)

(52) **U.S. Cl.**

CPC ***H01T 21/02*** (2013.01); ***H01T 13/32*** (2013.01); ***H01T 21/06*** (2013.01)

(58) **Field of Classification Search**

CPC H01T 21/02

See application file for complete search history.

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(57) **ABSTRACT**

A method of manufacturing an electrode composite for forming an electrode of a spark plug, the electrode composite being formed by laser-welding a first electrode member and a second electrode member together.

5 Claims, 13 Drawing Sheets

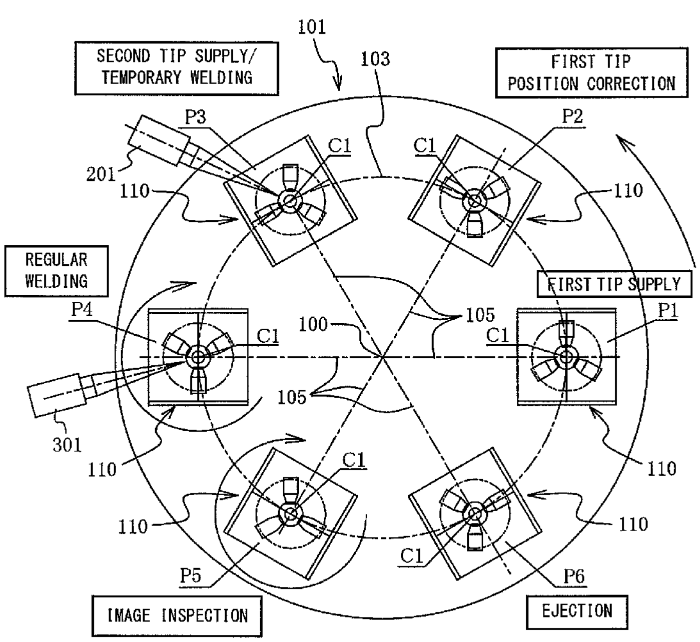


FIG. 1

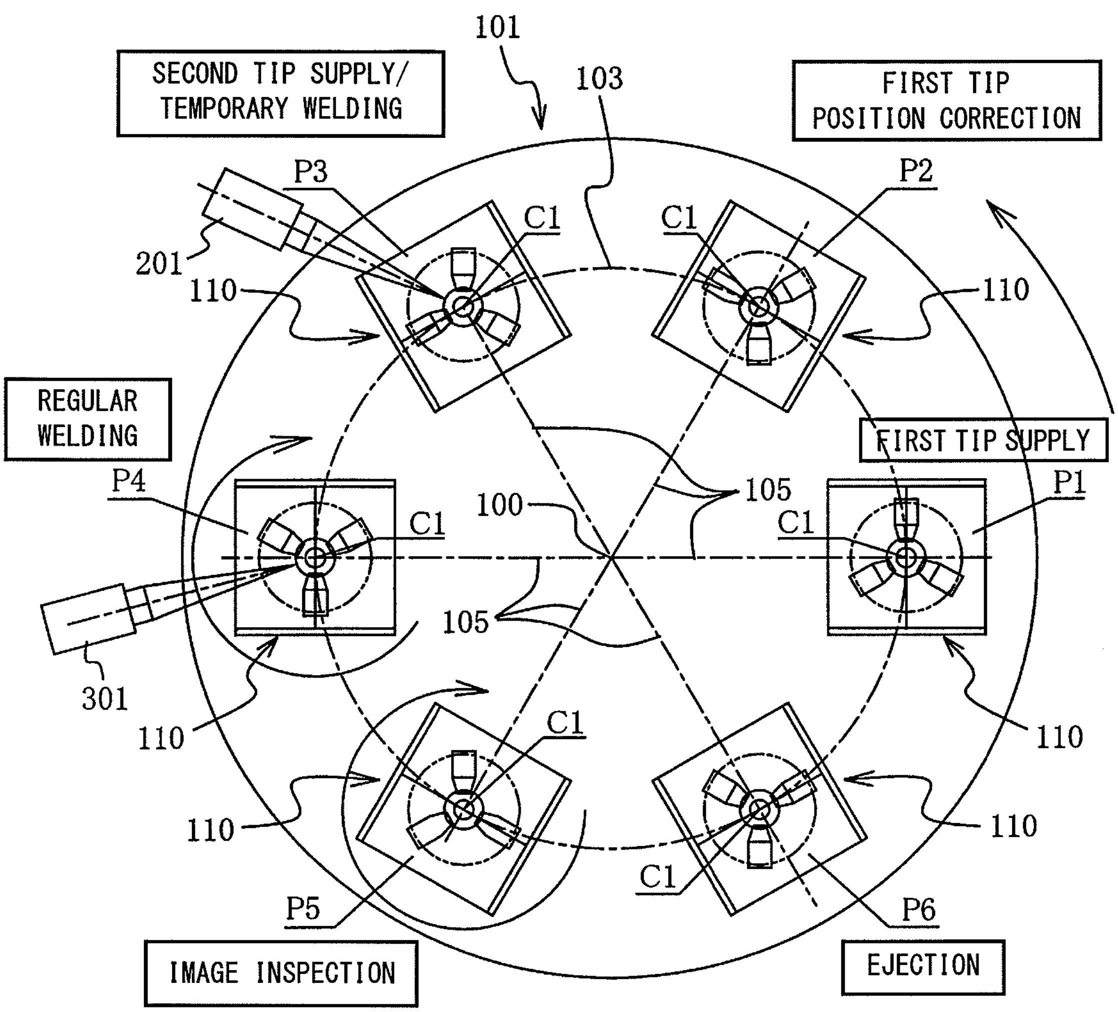

101
103
SECOND TIP SUPPLY/
TEMPORARY WELDING
FIRST TIP
POSITION CORRECTION
P3
C1
C1
P2
201
110
110
REGULAR
WELDING
FIRST TIP SUPPLY
P4
105
P1
100
C1
C1
105
301
110
110
C1
110
110
C1
P5
P6
IMAGE INSPECTION
EJECTION

FIG. 2

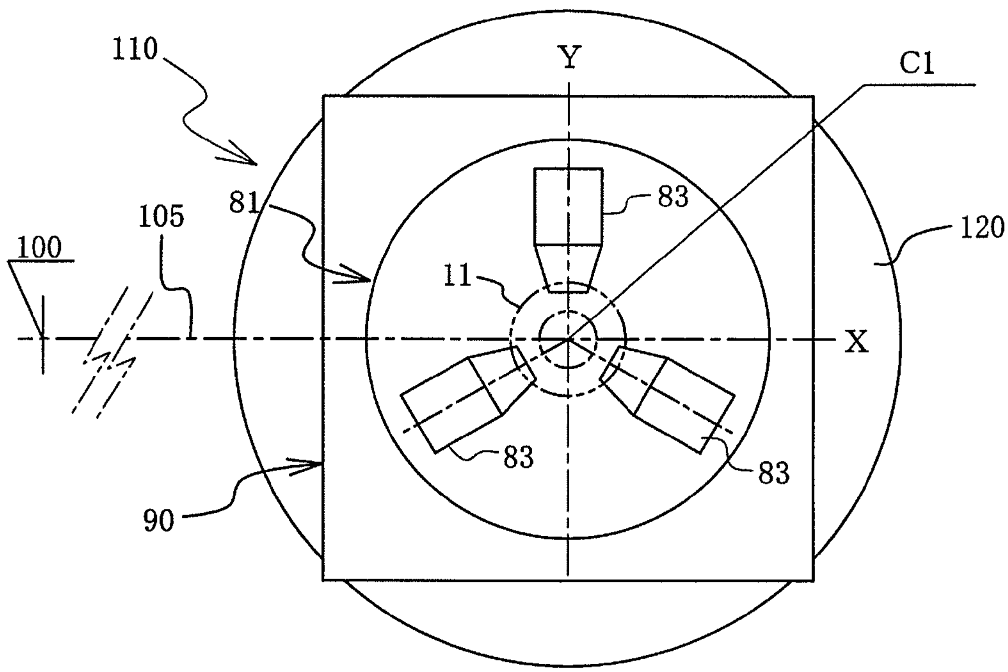


FIG. 3

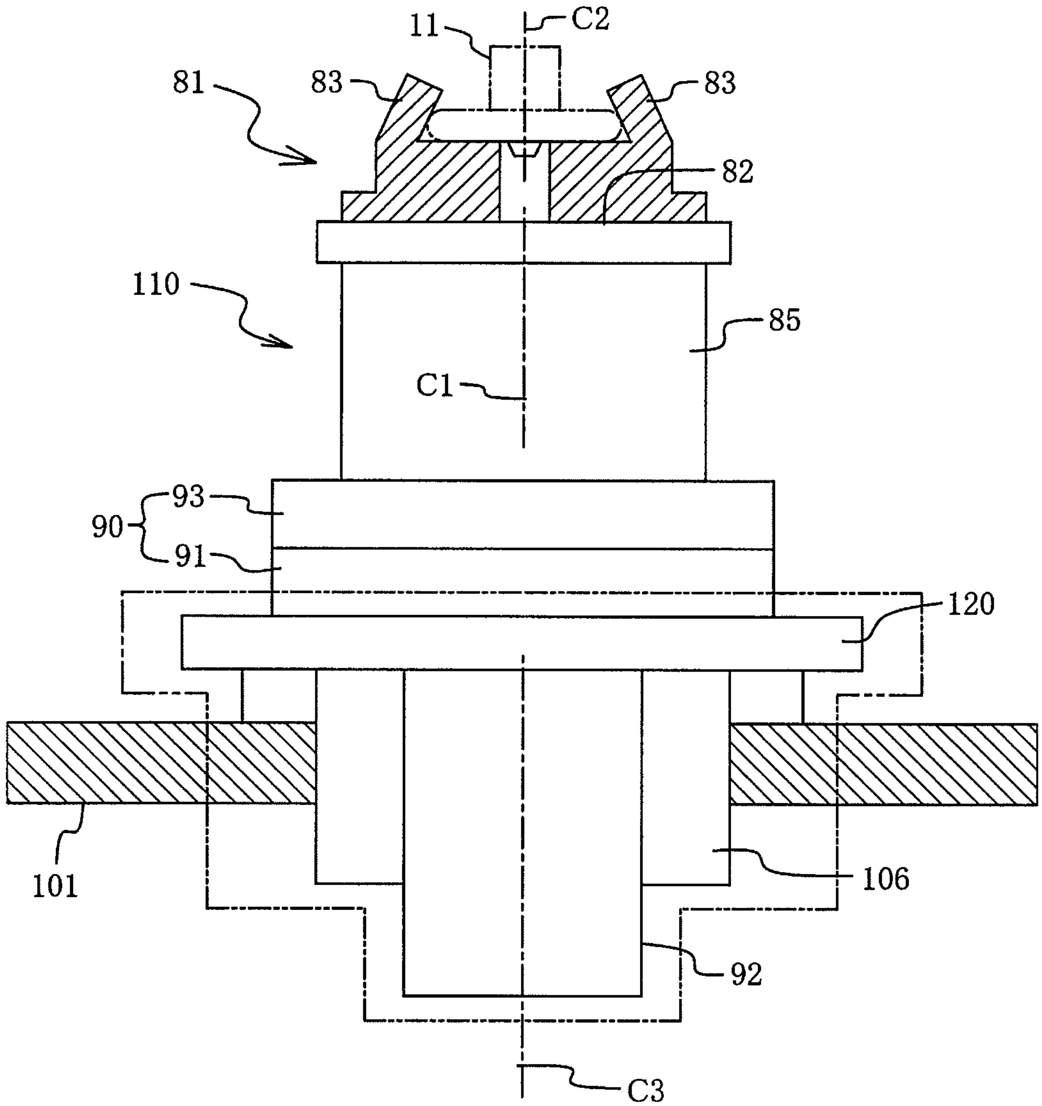


FIG. 4

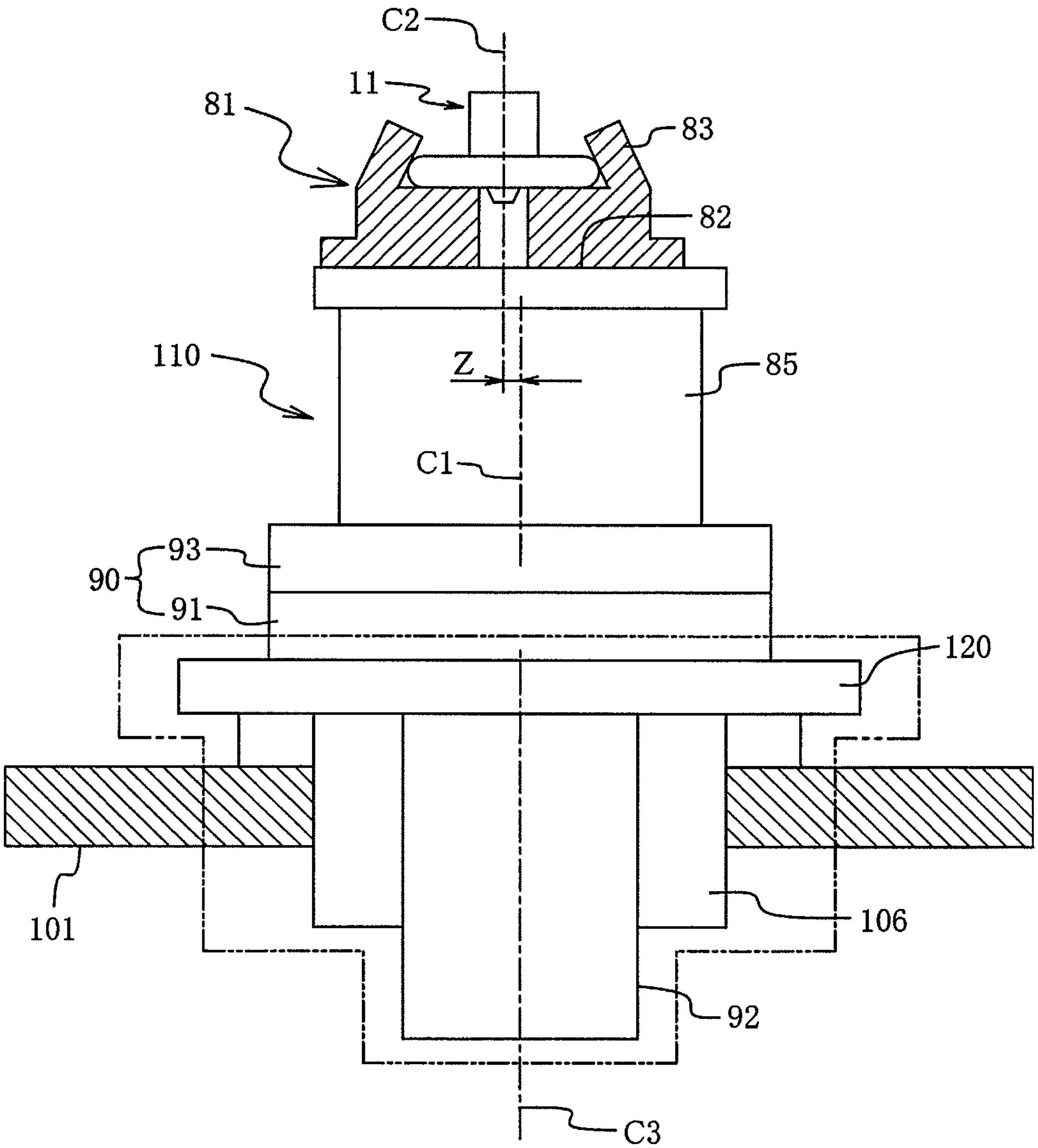


FIG. 5

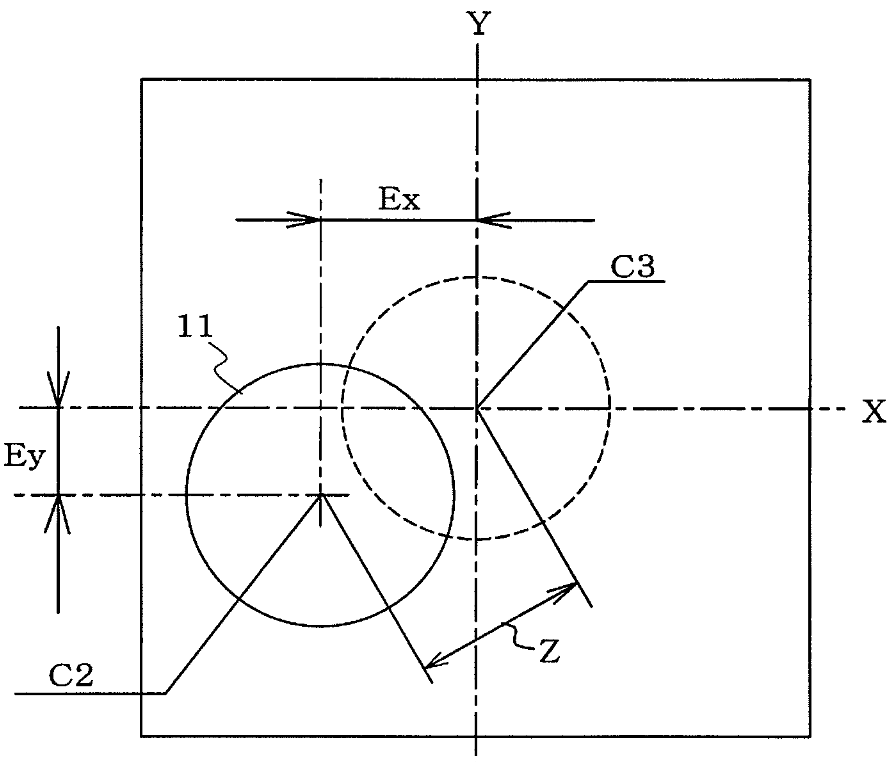


FIG. 6

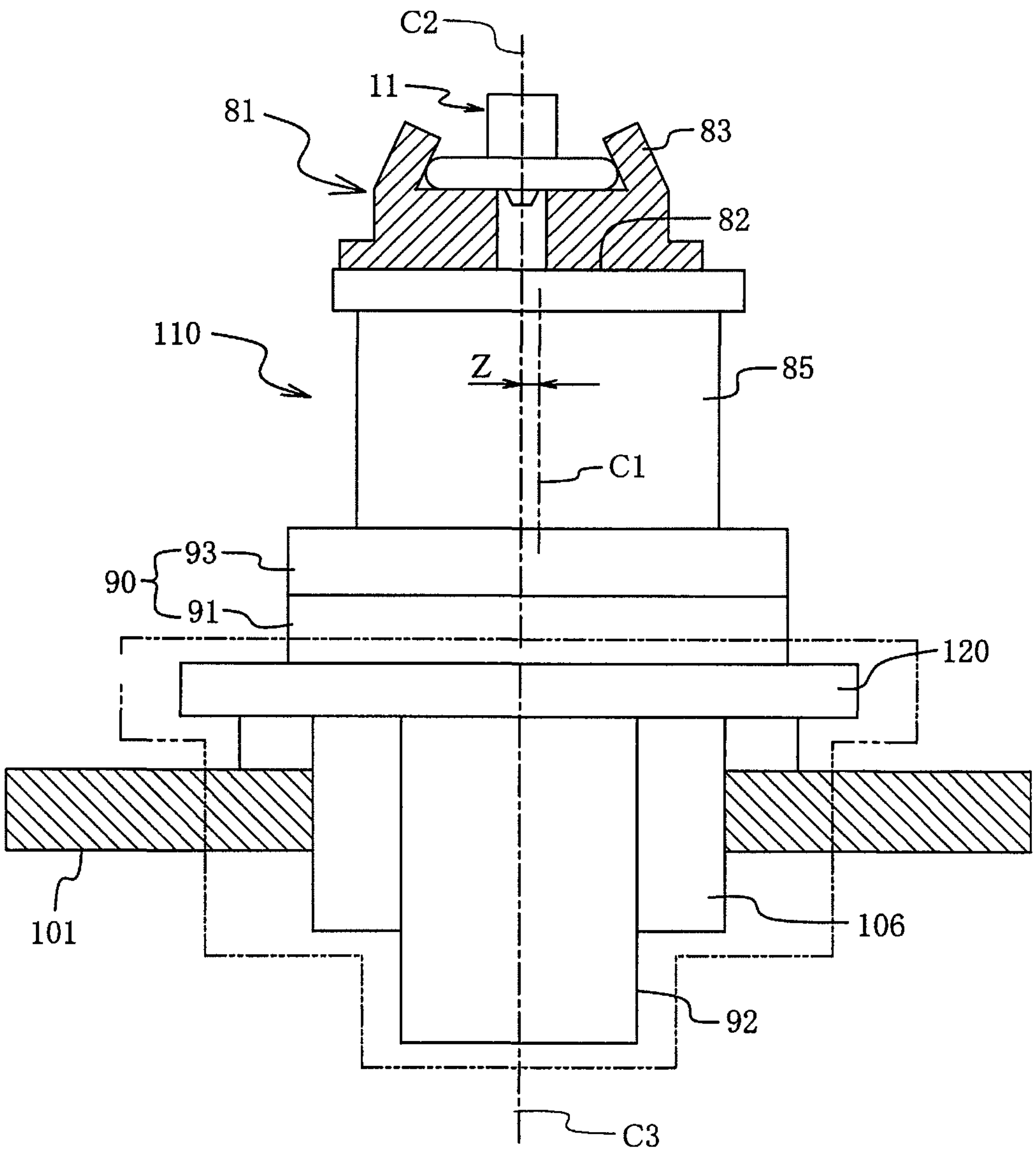


FIG. 7

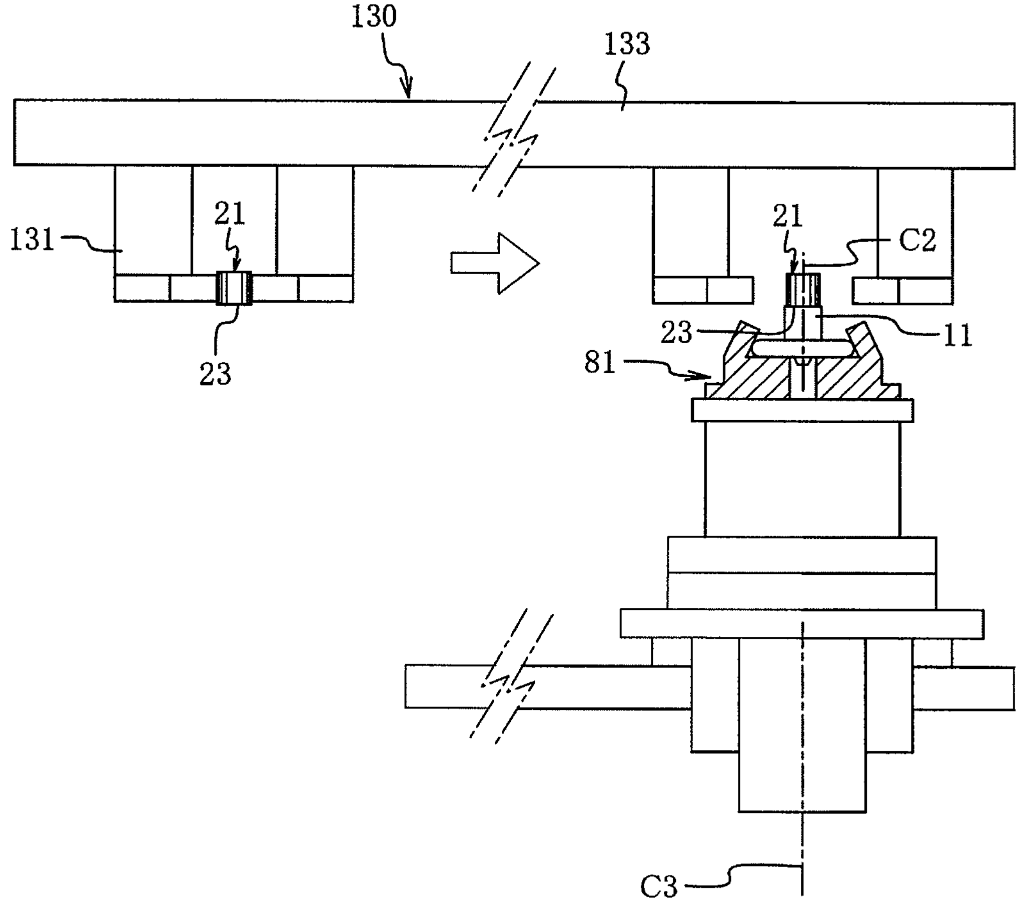


FIG. 8

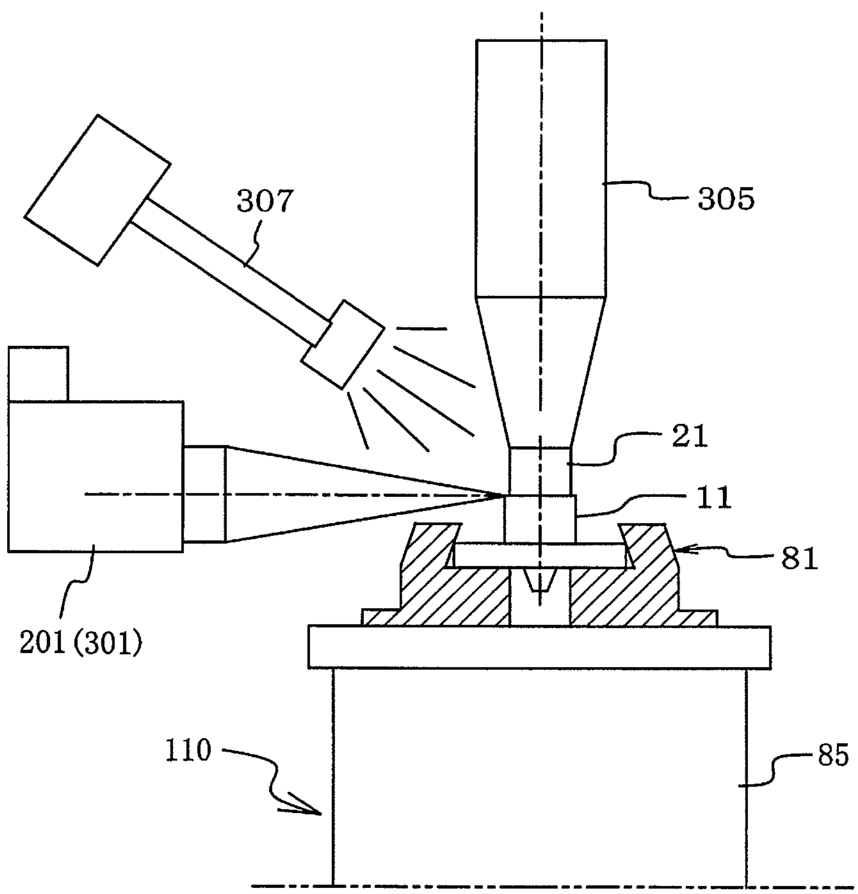
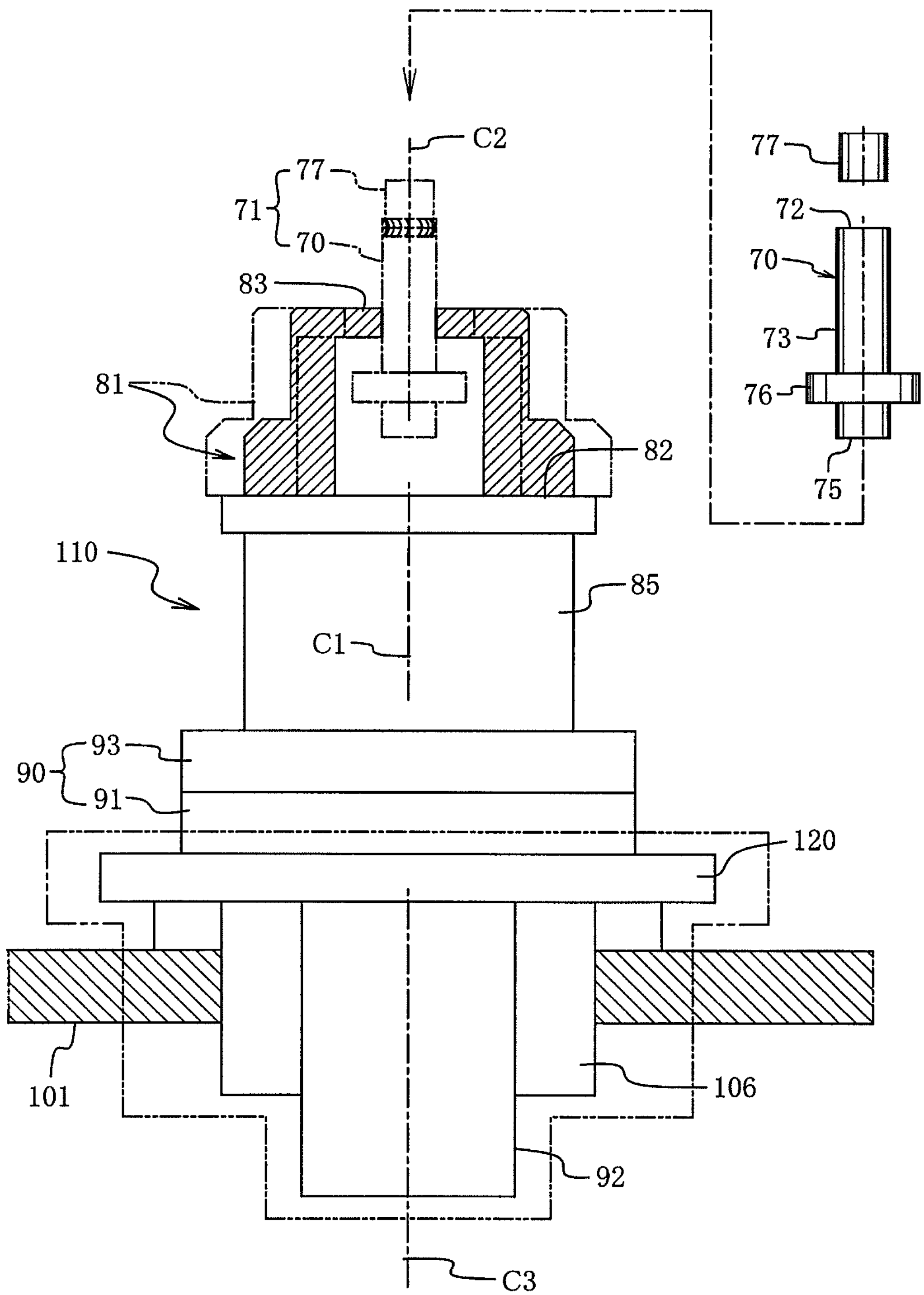


FIG. 9



C2
77
71
70
83
81
82
110
85
C1
93
90
91
120
101
106
92
C3
77
72
70
73
76
75

FIG. 10A

FIG. 10B

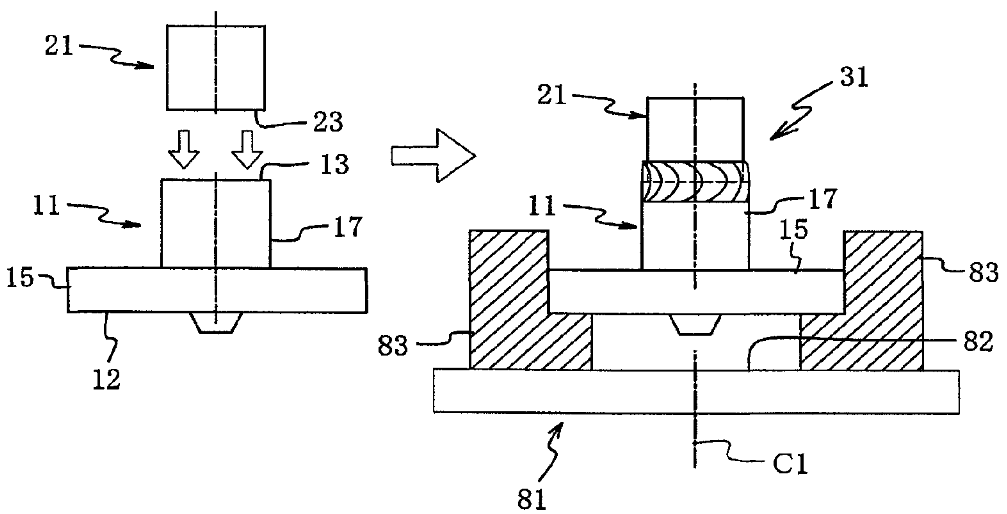


FIG. 11

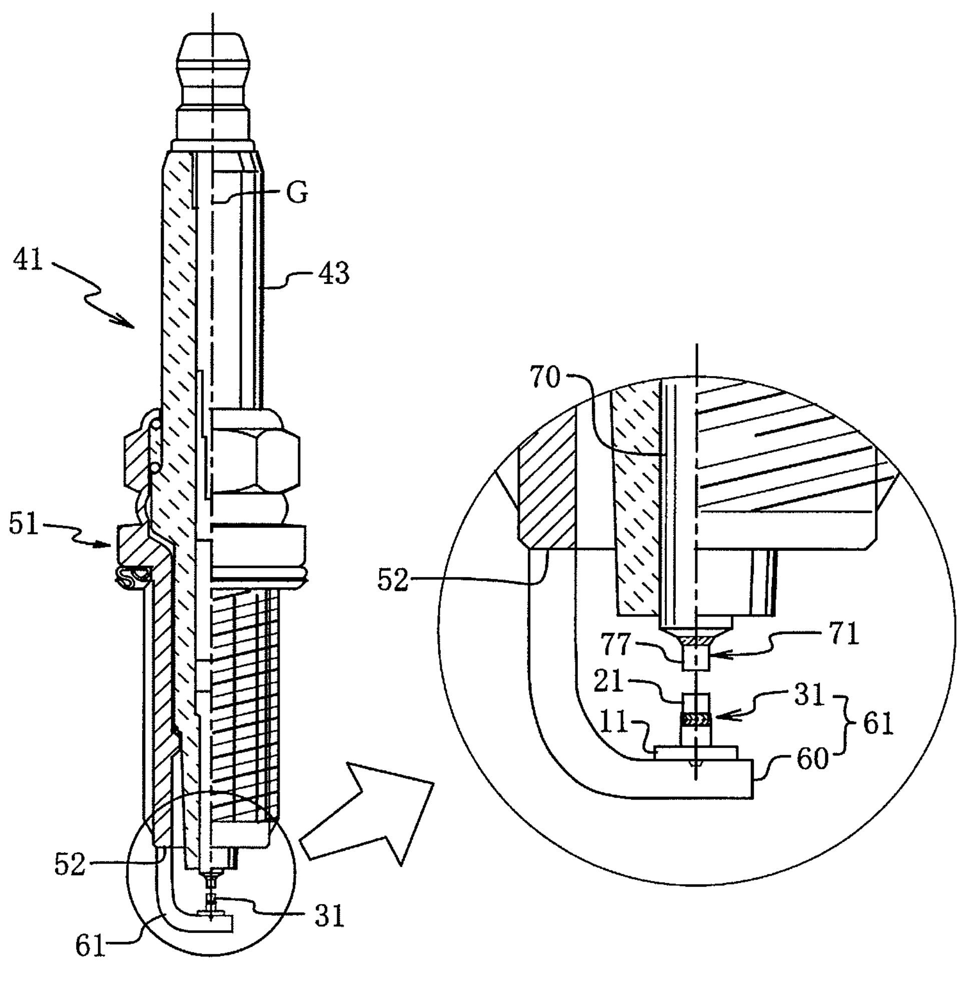


FIG. 12

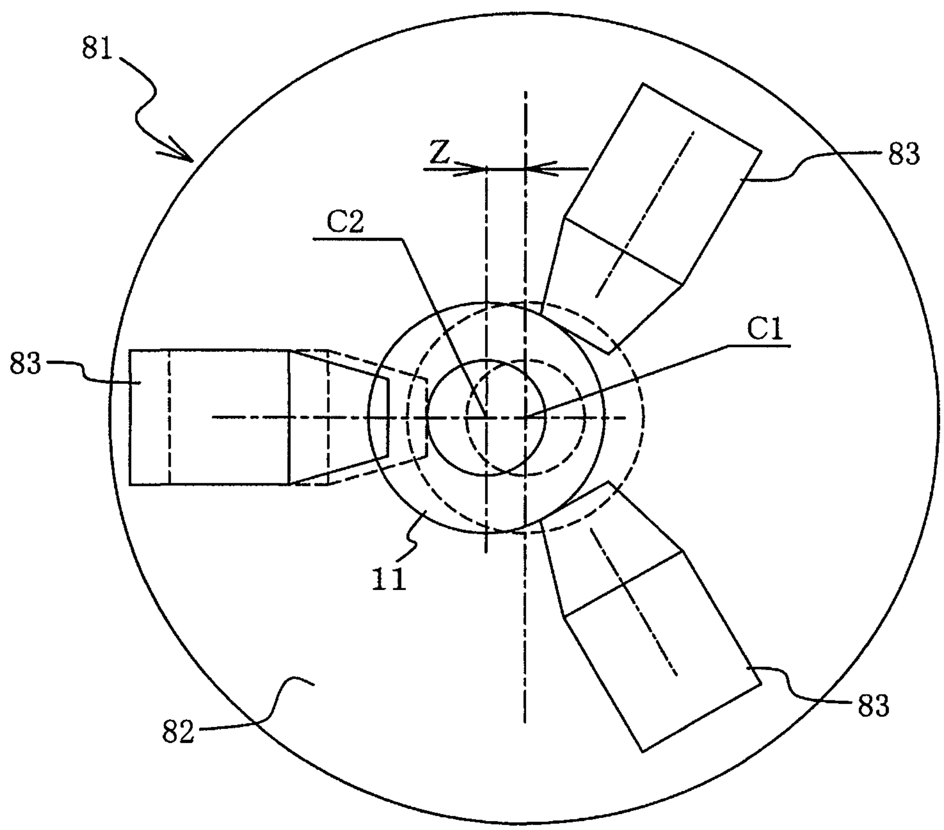
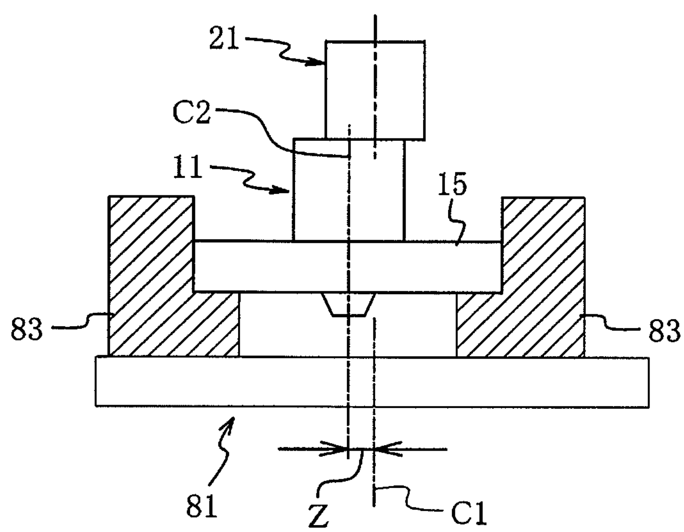


FIG. 13



METHOD OF MANUFACTURING ELECTRODE COMPLEX FOR FORMING ELECTRODE OF SPARK PLUG, AND METHOD OF MANUFACTURING SPARK PLUG

FIELD OF THE INVENTION

The present invention relates to a spark plug used for providing ignition in an engine, and more particularly to a method of manufacturing an electrode composite used to form an electrode of the spark plug, the electrode composite being formed by welding a first electrode member and a second electrode member together, and to a method of manufacturing a spark plug.

BACKGROUND OF THE INVENTION

In some spark plugs, in order to enhance ignition performance, a noble metal tip of platinum, iridium, or the like is fixed by welding to the end of a center electrode or a ground electrode located on a side toward a spark gap. Recently, in order to reduce costs of the electrodes, strong demand has arisen to reduce the diameter and size of a noble metal tip. In order to implement a reduction in diameter and size of the noble metal tip, welding the noble metal tip directly to an electrode is not efficient. Thus, there is known a spark plug configured as follows. Japanese Patent Application Laid-Open (kokai) No. 2004-134209 and Japanese Patent Application Laid-Open (kokai) No. 2009-158408 discloses a spark plug, wherein, in place of a sole noble metal tip, there is provided a tip body (hereinafter, may be referred to as the first tip) **11**, which corresponds to a first electrode member and is formed from Ni, etc., and a noble metal tip (hereinafter, may be referred to as the second tip) **21**, which corresponds to a second electrode member and is formed separately in a size smaller than conventionally known, as illustrated in FIG. **10**A. As shown in FIG. **10**B, the tip body **11** and the noble metal tip **21** are positioned and welded together into a composite tip **31**, which corresponds to an electrode composite. The composite tip **31** is welded via the tip body **11** to, for example, a ground electrode body formed at the forward end of a metallic shell of the spark plug (or welded to a center electrode body).

FIG. **11** shows an example of such a spark plug **41**. The spark plug **41** has an insulator **43**. A center electrode **71** is disposed in a forward end portion of an axial bore of the insulator **43**, and a metallic shell **51** surrounds the insulator **43**. A ground electrode **61** has one end joined to a forward end **52** of the metallic shell **51** and another end facing the forward end of the center electrode **71**. The ground electrode **61** is configured such that the composite tip **31**, which is formed by joining the first tip **11** and the second tip **21** together, is joined to a ground electrode body **60**.

The noble metal tip (the second tip) **21** assumes the form of a very small circular columnar shape having an outside diameter of 1 mm or less (e.g., about 0.7 mm to 0.8 mm) and a height of about 0.5 mm. The joining surface of the mate tip body (the first tip) **11** to which an end surface **23** of the second tip **21** is to be welded; i.e., an end surface (a distal end surface) **13** of the tip body **11**, also has a very small outside diameter of about 0.8 mm. A portion **15** of the mate first tip **11**, that is to be joined to an electrode (the center electrode or the ground electrode), has a relatively large outside diameter. Accordingly, as shown in FIG. **10**, the first tip usually has a concentrically stepped circular columnar structure having different diameters such that the base portion **15** having an end surface **12** to be joined to an electrode (the center electrode or the ground electrode) has a large diameter, whereas the end surface (the distal end surface) **13** to which the second tip **21** is to be welded has a small diameter.

Meanwhile, the end surface **23** of the second tip **21** is welded to the small-diameter distal end surface (the end surface) **13** of the first tip **11** conventionally in the following manner. For example, as shown in FIG. **10**, while the first tip **11** is held by a chuck **81**, the second tip **21** is positioned and disposed on and then welded to the first tip **11**. In this case, the first tip **11** is held by chucking the outer circumferential surface of the large-diameter base portion **15** of the first tip **11**. The end surface **23** of the second tip **21** is then concentrically positioned and placed on the end surface **13** of a small-diameter circular columnar portion **17** of the chucked first tip **11**. The other end surface of the second tip **21** is pressed with a press pin (not shown). Under the pressed condition, the chuck **81** is rotated about its center axis C**1**, and the end surfaces to be joined of the two tips **11** and **21** are circumferentially laser-welded along their outer circumferences.

A collet chuck mechanism having a plurality of chuck claws (hereinafter, may be referred to merely as claws) **83** is usually used in the chuck **81**. As shown in FIG. **12**, the chuck **81** has the following configuration: when a single cylinder (not shown) is driven, claws **83** which are disposed orthogonal to a rod of the cylinder and, as viewed from the axial direction of the rod, usually at equal angular intervals (divided evenly into thirds) simultaneously move forward at the same speed in respective closing directions, thereby clamping the first tip **11**. Thus, theoretically, the first tip **11** is fixed concentric with a reference center (reference center axis) C1 of a chuck surface **82**.

However, when the first tip **11** is held, i.e., chucked, within the chuck **81**, as exaggeratedly represented with the solid lines in FIG. **12**, the first tip **11** is fixed in such a condition as to involve a positional deviation (eccentric error) Z, which is in many cases a very small amount, from a position concentric with the reference center (the reference center axis of the chuck) C**1** of the chuck surface **82**, as represented with the dashed circles in FIG. **12**. That is, as shown in FIG. **12**, the first tip **11** is fixed such that an actual center axis (may be called the center) C**2** of the first tip **11** is eccentric to the reference center axis C**1** of the chuck **81**. This is for the following reason: regardless of a collet chuck, in a chuck having a plurality of claws, in view of the mechanism thereof, it is impossible to move the claws forward 100% simultaneously at the same speed over the same stroke in units of several-μm. Therefore, holding the first tip **11** with the chuck **81** involves a problem that, at a minimum, produces a positional deviation Z of about 0.025 mm from the reference center axis C1 of the chuck on one side.

Meanwhile, as shown in FIG. **13**, when the second tip **21** is supplied and disposed in relation to the first tip **11** chucked under the condition that such a positional deviation Z is involved, since the preset reference center axis C1 of the chuck **81** is fixed, by means of controlling disposition of the second tip **21** with respect to the center axis C**1**, the positional error of the center axis of the second tip **21** with respect to the reference center axis C1 of the chuck **81** can be restrained to a negligibly small level (an error on the order of about 0.005 mm) as compared with an unavoidable error peculiar to the chuck mechanism. That is, by use of a supply means which employs a servomechanism or the like, the second tip **21** can be disposed with involvement of substantially no error; i.e., with high accuracy, with respect to the reference center axis C1 of the chuck **81**. Therefore, in view of an error peculiar to the chuck mechanism which unavoidably arises at the time of chucking the first tip, a conventional manufacturing method needs to employ an eccentric error Z of at least about ±0.025 mm on one side as tolerance for the center runout (coaxiality) of the second tip in relation to the first tip.

In this regard, in order to improve performance of a spark plug, demand for improvement of dimensional accuracy associated with welding of the second tip to the first tip is becoming stronger and stronger. Specifically, a currently required tolerance on coaxiality (eccentric error) between the first and second tips is about 0.01 mm to 0.015 mm on one side. Thus, for a method in which the first tip is fixed with the above-mentioned chuck or the like, and the second tip is supplied and welded to the fixed first tip, difficulty is encountered in satisfying such a severe tolerance requirement for coaxial accuracy.

According to conceivable measures to overcome the above problem, after the second tip is supplied and disposed on the first tip held by a chuck, coaxiality (eccentricity) between the first and second tips is measured or detected through image processing or the like, and positional correction is performed for example, by shifting, according to the measured eccentricity (error), the second tip so as to be aligned with the center axis of the first tip. However, since such positional correction is performed after the second tip is supplied and disposed on the first tip, the end surfaces of the tips in contact with each other rub against each other, potentially resulting in the occurrence of a defect, such as scratches, on the end surfaces. Also, since the positional correction is performed after the second tip is supplied and disposed on the first tip, the number of steps increases. As a result, the efficiency in manufacturing a composite tip may drop, and in turn, spark plug productivity may drop. Furthermore, when, subsequent to the positional correction in which the second tip is positionally shifted so as to be coaxial with the first tip held by the chuck, welding is performed on the outer circumferential edges of the joining surfaces of the tips while the chuck is rotated, the center of rotation of the chuck is the reference center axis C**1** of the chuck, whereas the actual center axes of the tips deviate by an error from the reference center axis C**1**. Thus, there also arises a problem that the distance between a laser welding apparatus and a region to be welded (laser radiation distance) varies with rotation of the chuck.

The above-mentioned problem is not limited to the case of manufacturing the composite tip, which corresponds to an electrode composite, formed by welding together the first tip (the tip body), which corresponds to the first electrode member, and the second tip (the noble metal tip), which corresponds to the second electrode member. In the spark plug **41** shown in FIG. **11**, the center electrode **71** assumes the form of an electrode composite composed of a center electrode body **70**, which corresponds to the first electrode member, and an electrode tip **77**, which is welded to the forward end of the center electrode body **70** and corresponds to the second electrode member. Manufacturing the center electrode **71** in the form of such an electrode composite also involves the above-mentioned problem, for the following reason: even in manufacture of the center electrode **71**, by use of an apparatus similar to that mentioned above, the center electrode body **70** is chucked; the electrode tip **77** is supplied and then positioned and disposed on the forward end of the center electrode body **70**; and steps similar to those mentioned above are carried out. That is, manufacturing not only the above-mentioned composite tip **31** and the center electrode **71**, but also an electrode composite formed through welding of the first electrode member and the second electrode member and adapted to form an electrode of a spark plug has involved a similar problem for a reason similar to that mentioned above.

SUMMARY OF THE INVENTION

The present invention has been conceived in view of the above problem. An advantage of the present invention is a method of efficiently manufacturing an electrode composite for forming an electrode of a spark plug, such as a composite tip formed by efficiently disposing a noble metal tip (a second tip), which corresponds to a second electrode member, on a first tip (a tip body), which corresponds to a first electrode member, with high coaxial accuracy so as to prepare for welding, and then welding the tips together, without involvement of a drop in manufacturing efficiency and the occurrence of a defect, such as scratches, as well as a method of manufacturing a spark plug.

In accordance with the present invention, there is provided a method of manufacturing an electrode composite for forming an electrode of a spark plug, the electrode composite being formed by laser-welding a first electrode member and a second electrode member together,

the method comprising:

a first electrode member holding step of holding the first electrode member by a chuck of a chuck unit;

a second electrode member supply step of supplying the second electrode member such that an end surface of the second electrode member comes into contact with an end surface of the first electrode member; and

a laser welding step of welding outer circumferential edges of the end surfaces through which the first electrode member and the second electrode member are in contact with each other;

the method being characterized by further comprising:

an eccentric error detection step coming after the first electrode member holding step and before the second electrode member supply step and adapted to detect an eccentric error between a position of an actual center axis of the first electrode member and a shaft of a base rotatably supporting the chuck of the chuck unit, and

a center axis position correction step of correcting the position of the actual center axis of the first electrode member when the eccentric error detected in the eccentric error detection step falls outside a tolerance range subsequent to the eccentric error detection step, so as to align the actual center axis of the first electrode member with an axis of the shaft of the base.

In accordance with another aspect of the present invention, there is provided a method of manufacturing an electrode composite for forming an electrode of a spark plug, as described above, characterized by further comprising a temporary welding step coming after the second electrode member supply step and before the laser welding step and adapted to temporarily weld the outer circumferential edges of the end surfaces through which the first electrode member and the second electrode member are in contact with each other.

In accordance with another aspect of the present invention, there is provided a method of manufacturing an electrode composite for forming an electrode of a spark plug, as described above, characterized in that:

a plurality of the chuck units are disposed on revolvingly moving means so as to sequentially move in association with revolution of the revolvingly moving means, and

the eccentric error detection step and the center axis position correction step are performed at the same position in the course of revolution.

In accordance with still another aspect of the present invention, there is provided a method of manufacturing an electrode composite for forming an electrode of a spark plug as described above, characterized in that:

a plurality of the chuck units are disposed on revolvingly moving means so as to sequentially move in association with revolution of the revolvingly moving means, and

the first electrode member holding step and the eccentric error detection step are performed at different positions in the course of revolution.

In accordance with another aspect of the present invention, there is provided a method of manufacturing a spark plug which has an insulator having an axial bore in a direction of an axis, a center electrode disposed in a forward end portion of the axial bore, a metallic shell circumferentially surrounding the insulator, and a ground electrode whose one end is joined to the metallic shell and whose other end faces a forward end of the center electrode, and in which the center electrode or the ground electrode is an electrode composite formed by joining a first electrode member and a second electrode member together, or is formed by joining the electrode composite,

the method being characterized in that the electrode composite is manufactured by a manufacturing method described above.

According to the present invention, even though, when the first electrode member (e.g., a first tip; hereinafter, may be referred to as the first tip) is held by the chuck, the actual center axis of the first tip involves an eccentric error with respect to the reference center axis of the chuck; i.e., the shaft of the base (the shaft of the chuck unit) rotatably supporting the chuck of the chuck unit, and the eccentric error falls outside a tolerance range, before the second electrode member (e.g., a second tip; hereinafter, may be referred to as the second tip) is supplied and then positioned and disposed on the first tip, the position of the actual center axis of the first tip is corrected so as to be aligned with the axis (the position of the axis) of the shaft of the base of the chuck unit. Therefore, the thus-corrected position of the first tip coincides with the position of the shaft without involvement of an error associated with chucking. Thus, when the second tip is supplied and then positioned and disposed on the first tip located at such a position, the first and second tips can be readily disposed with highly accurate coaxiality. Subsequently, when the first and second tips are welded while the chuck unit is rotated about the axis of the shaft, since the center axes of the first and second tips maintain high coaxiality with the shaft, an electrode composite having high coaxial accuracy can be yielded efficiently.

Also, the present invention does not employ an aligning method, wherein the coaxiality (eccentric error) of the second tip with respect to the first tip is adjusted. If after the second tip is supplied and then positioned and disposed on the first tip held by the chuck, coaxiality between the first and second tips is measured, and the measured coaxiality involves an error which falls outside tolerance. Therefore, joining surfaces (the end surfaces of the first and second tips in contact with each other) do not rub each other and thus are free from scratching. Notably, as in the case of the invention described above, addition of the temporary welding step improves the efficiency of a regular welding step.

As described above, the eccentric error detection step and the center axis position correction step may be performed at the same position in the course of revolution. Also, as described above, preferably, the first electrode member holding step and the eccentric error detection step are performed at different positions in the course of revolution. Specifically, after the first electrode member; for example, the first tip, is supplied and held, the revolvingly moving means is driven to move by a predetermined amount the chuck unit which holds the first tip. At a position where the chuck unit stops; i.e., at a position different from the first tip supply position, the position of the actual center axis of the first tip held by the chuck unit is measured by image processing, and an eccentric error between the position of the actual center axis of the first tip and the shaft of the chuck unit is detected. In this manner, by means of performing these steps at different positions rather than at one position, working time at the individual steps can be reduced, whereby efficiency in manufacture of the electrode composite (e.g., a composite tip) can be enhanced. As described above, according to the present invention, the second electrode member can be joined to the first electrode member without involvement of a deterioration in coaxiality and scratching on the joining surfaces, whereby a highly accurate electrode composite can be efficiently manufactured.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic configurational view showing a circular table, on which chuck units are disposed, of a manufacturing apparatus used in a manufacturing method of the present invention, as viewed from above the circular table.

FIG. **2** is an enlarged explanatory view showing the chuck unit at the start position of a manufacturing process, as viewed from above the chuck unit.

FIG. **3** is an enlarged elevational view for explaining the chuck unit of FIG. **2**.

FIG. **4** is a view for explaining an eccentric error Z involved when a first tip, which corresponds to a first electrode member, is fixed by a chuck in FIG. **3**.

FIG. **5** is a conceptual view for explaining measurement of eccentric error.

FIG. **6** is an explanatory view showing a condition after an actual center axis C**2** of the first tip, which corresponds to the first electrode member, shown in FIG. **4** is positionally corrected by driving a chuck position adjustment means so as to be aligned with an axis C**3** of a shaft.

FIG. **7** is a view for explaining an operation of supplying a second tip, which corresponds to a second electrode member, to the first tip, which corresponds to the first electrode member, shown in FIG. **6** and then positioning and disposing the second tip on the first tip.

FIG. **8** is an explanatory view for laser welding.

FIG. **9** is an enlarged elevational view for explaining a chuck unit in the case where an electrode composite to be manufactured in FIG. **3** is a center electrode.

FIGS. **10**A and **10**B are a pair of views for explaining the configuration of a composite tip, wherein FIG. **10**A is for explaining component tips before welding, and FIG. **10**B is for explaining the composite tip after welding.

FIG. **11** is an explanatory view showing a spark plug using the composite tip.

FIG. **12** is an explanatory view for eccentric error which arises in fixing a first tip by a chuck.

FIG. **13** is an explanatory view showing disposition of a second tip on the first tip which involves eccentric error.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only, and not for the purpose of limiting the same, a manufacturing method according to an embodiment of the present invention will be described in detail. First, an electrode composite to be manufactured in the present embodiment will be described. The electrode composite to be manufactured in the present embodiment is a composite tip **31** shown in FIG. **10**B. As shown in FIG. **10**A, a first electrode member and a second electrode member which constitute the composite tip **31** are a first tip **11** and a second tip **21**, respectively. The composite tip **31** is described below in detail. The first tip (a tip body made of nickel) **11** of the composite tip **31** includes a disklike base portion **15** and a circular columnar portion **17** having a diameter (e.g., an outside diameter of 0.78 mm) smaller than that of the base portion **15** and concentrically protruding from the upper end surface of the base portion **15** in FIGS. **10**A and **10**B and thus have a shape resembling an inverted letter T. The first tip **11** also has a very small protrusion **19** having the shape of a truncated cone and concentrically protruding from an end surface (a bottom surface) **12** of the base portion **15** located on the opposite side (the lower side in FIGS. **10**A and **10**B). The second tip (a tip made of a noble metal (e.g., Pt)) **21** is similar to that shown in FIG. **10** and has a circular columnar shape having a diameter (an outside diameter of 0.75 mm) slightly smaller than that of the circular columnar portion **17** of the first tip **11**.

As shown in FIG. **10**B, the composite tip **31** is formed as follows: the second tip **21**, which will be located on a side toward a spark gap, is supplied to a position above an end surface **13** of circular columnar portion **17** (a small-diameter portion) of the first tip **11** and then positioned and disposed on the end surface **13** of the first tip **11** such that an end surface **23** of the second tip **21** is concentric with the end surface **13** of the first tip **11**, and the outer circumferential edges of the end surfaces **13** and **23** through which the first and second tips **11** and **21** are in contact with each other are laser-welded along a circumferential direction. As shown in FIG. **11**, in the present embodiment, the composite tip **31** is subsequently welded to a ground electrode body (or a center electrode) **61** welded to a forward end **52** of a metallic shell **51** for a spark plug, thereby configuring a spark plug **41**. In the present embodiment, allowable coaxiality (allowable eccentric error) is, for example, a very small amount of 0.015 mm on one side; i.e., tolerance for eccentric error is determined such that the second tip **21** does not protrude radially outward from the small-diameter circular columnar portion **17** of the first tip **11**.

Next, means (a manufacturing apparatus) used in the manufacturing method of the present embodiment for manufacturing the composite tip **31** by welding will be described in detail with reference to FIG. **1**, etc. In FIG. **1**, reference numeral **101** denotes a circular table, which serves as revolvingly moving means for revolvingly moving a plurality of similar chuck units **110**, which will be next described, in a simultaneous manner. FIG. **1** is a schematic configurational view showing the circular table **101** on which the chuck units **110** are disposed, as viewed from above the circular table **101**. The circular table is configured to be intermittently restated about its center by an unillustrated rotational drive means such that the circular table rotates by 60 degrees and stops in a repeated manner. In the present embodiment, the chuck units **110** of the same configuration are disposed and mounted with high dimensional accuracy on an imaginary circle **103** whose center coincides with a center **100** of the circular table **101**. The chuck units are mounted at six positions coinciding with intersections of the imaginary circle **103** and straight lines **105** which divide the imaginary circle **103** into six equal parts (intersections of the imaginary circle **103** and radial lines **105** drawn radially from the center **100** of the circular table **101** at equal angular intervals of 60 degrees), the intersections serving as centers C**1** of the chuck units **110**. Thus, when the circular table **101** rotates by 60 degrees, the chuck units **110** move (in the present embodiment, rotate (revolve) counterclockwise in FIG. **1**) accordingly along the imaginary circle **103**. As will be described later in detail, the chuck units **110** are disposed on the circular table **101** in such a manner as to be rotatable about their centers C**1** coinciding with the intersections of the imaginary circle **103** and the radial lines **105** which divide the imaginary circle **103** into six equal parts. FIG. **1** shows a state in which the circular table **101** is not rotating (at a rest).

Next, the chuck units **110** disposed on the circular table **101** will be described with reference to FIGS. **2** and **3**. Each of the chuck units **110** has, at its top, a chuck **81** of a collet chuck **81** type having a plurality of (in the present embodiment, three) chuck claws **83** which can hold the outer circumference of the base portion **15** of the first tip **11**. The chuck **81** has a chuck pedestal **85** at its lower portion, and the chuck pedestal **85** contains an unillustrated chuck drive means (such as an air cylinder) for opening and closing the chuck **81**. The chuck **81** is configured to encompass the chuck pedestal **85**. The chuck pedestal **85** which encompasses the chuck **81** is disposed on a conventionally known chuck position adjustment means **90** which can adjust the position of the reference center axis C**1** of the chuck **81** in two orthogonal directions (X and Y directions) as viewed in plane. The chuck position adjustment means **90** includes a lateral slide member (table) **91** which slides on a base **120** along a guide, for example, in the X direction as viewed in plane; a longitudinal slide member **93** which slides on the lateral slide member (table) **91** along a guide in the Y direction orthogonal to the X direction as viewed in plane; and a servomechanism (not shown) for driving the lateral and longitudinal slide members **91** and **93** in the X and Y directions, respectively. The chuck pedestal **85** is fixedly supported on the longitudinal slide member **93** of the chuck position adjustment means **90**. The bases **120**, which support the respective chuck position adjustment means **90**, are disposed on the circular table **101** such that shafts **92** provided at their bottoms are supported by respective bearings **106**. The bearings **106** are disposed with high accuracy such that their centers coincide with the intersections of the above-mentioned imaginary circle **103** of the circular table **101** and the radial lines **105** drawn at 60-degree intervals. The shafts **92** are rotated by respective chuck unit rotational-drive means (not shown). By means of rotationally driving the shafts **92**, the respective chuck units **110** are rotated on the circular table **101**. The reference center axis C**1** of each of the chucks **81** is held coaxially with an axis C**3** of the corresponding shaft **92** (the chuck **81** and the shaft **92** share the same axis) and serves as a design reference position.

As mentioned above, in the present embodiment, by means of the shaft **92** being rotated in relation to the circular table **101**, the base **120** integral with the shaft **92**, the chuck position adjustment means **90** provided on the base **120**, and the chuck unit **110** encompassing the chuck **81** and provided on the chuck position adjustment means **90** can be rotated via rotational drive means (not shown). Also, the shaft **92** and the reference center axis C**1** of the chuck **81** become coaxial with each other when the chuck position adjustment means **90** is situated at the reference position. Thus, when, under the condition that the chuck position adjustment means **90** is situated at the reference position, the shaft **92** is rotated in relation to the circular table **101**, the chuck **81** is rotated about the reference center axis C**1** aligned with the axis (centerline) of the shaft **92**. In the present embodiment, the shaft **92** is rotated when the circular table **101** is at halters, i.e., stationary, in the course of revolution (in the course of rotation).

Next will be described a process of manufacturing the composite tip **31**, which corresponds to the electrode composite, in the present embodiment by intermittently rotating the above-mentioned circular table **101**. The following description assumes that, in the present embodiment, the far right position in FIG. **1** is a position at which the first tip **11**, which corresponds to the first electrode member, is supplied and disposed; i.e., a start position (first position) P**1** of the process. First, the entire process will be briefly described. The circular table **101** is rotationally driven and then stopped. First tip supply means (first electrode member supply means, not shown) supplies the first tip **11** to the chuck **81** of the chuck unit **110**, which is at the start position, and disposes the first tip **11** from above the chuck **81** such that the base portion **15** of the first tip **11** faces a chuck surface **82**; and the chuck **81** holds (chucks) the first tip **11**. Then, the circular table **101** is rotated (counterclockwise) by 60 degrees and then stopped. By repeating this operation, the chuck unit **110** is transmitted sequentially from a second position P**2** to a sixth position P**6** along a circular path (the circumference of the imaginary circle **103**) and undergoes the following steps at individual stop positions. At the second position P**2** and subsequent positions (stop positions), the following steps are performed sequentially: positional correction of the first tip **11**; supply and temporary welding of the second tip **21**, which corresponds to the second electrode member; regular welding of the first tip **11** and the second tip **21**; image inspection of welded condition, etc.; and ejection (delivery) of the composite tip **31**, which corresponds to the electrode composite formed by welding. These steps will be sequentially described below, starting from the step at the start position (first position) P**1**.

At the start position (first position) P**1**, the first tip **11** is supplied to the chuck **81**, which is in an opened condition. Then, a first tip holding step (hereinafter, may be referred to as the first tip holding step), which corresponds to a first electrode member holding step, is performed; specifically, as mentioned above, the claws **83** of the chuck **81** are driven so as to chuck and hold the outer circumferential surface of the base portion **15** of the first tip **11**. The chuck **81** in the present embodiment is configured such that, as viewed in plane, three chuck claws **83** disposed at three equal angular intervals simultaneously move along the chuck surface **82** by the same amount toward the center of the chuck **81**. That is, the chuck **81** is configured as follows: when the first tip **11** is placed in such a manner that the center of its base portion **15** is positioned at the reference center axis C**1** of the chuck **81**, the three claws **83** radially clamp the outer circumferential surface of its base portion **15**. In the present embodiment, as shown in FIG. **3**, each of the chuck claws **83** has an inner surface (located on a side toward the reference center axis C**1**) inclined by an appropriate amount (5 degrees to 15 degrees) in such a manner as to approach the reference center axis C**1** as the distance from the chuck surface **82** increases, so as to generate a component force that presses (pulls) the base portion **15** toward the chuck surface **82** when the claws **83** clamp the base portion **15**. This prevents the first tip **11** from separating from the chuck surface **82** when the first tip **11** is chucked by the chuck **81**. A conventionally known parts feeder, which serves as the first tip supply means, supplies the first tip **11** such that its base portion **15** is disposed on the chuck surface **82** at the center of the chuck **81** in opened condition at the first position P**1**.

As shown in FIG. **4**, the first tip **11** chucked at the first position P**1** through execution of the above-mentioned first tip holding step involves a positional deviation such that because of a very small difference in advancing speed and stroke among the claws **83**, the actual center axis C**2** of the first tip **11** deviates by a very small positional deviation (eccentric error) Z from the reference center axis C**1** of the chuck **81** or the axis C**3** of the shaft **92**, and, as mentioned above, the eccentricity is about 0.025 mm on one side.

Next, after the first tip **11** is chucked at the start position as mentioned above, the circular table **101** is rotated by 60 degrees and then stopped. By this operation, the chuck unit **110** in a state of chucking the first tip **11** is moved to the second position and then stopped there. In the present embodiment, at the stop position (second position) P**2**, the first tip **11** held by the chuck **81** is measured for the position of its actual center axis C**2** by image processing. As shown in FIG. **5**, there are detected eccentricities in the X and Y directions (eccentric errors Ex and Ey) between the position of the actual center axis C**2** of the first tip **11** and a preset position (regular reference position) where the center axis of the first tip **11** is expected to be situated at the stop position. In the present embodiment, since the reference position is also the position of the shaft **92** of the chuck unit **110**, there is detected the eccentric error Z in plane of the position of the actual center axis C**2** of the first tip **11** with respect to the position of the axis C**3** of the shaft **92**.

In an eccentric error detection step at the second position P**2**, when the eccentric error Z falls outside a tolerance range, the above-mentioned chuck position adjustment means **90** is driven so as to correct the planar position of the chuck **81** for aligning the position of the actual center axis C**2** of the first tip **11** with the position of the axis C**3** of the shaft **92** as shown in FIG. **6**. In the present embodiment, this center axis position correction step for the first tip is performed as follows: the above-mentioned lateral and longitudinal slide members **91** and **93**, which constitute the chuck position adjustment means **90**, are slidingly driven by predetermined amounts in the X and Y directions, respectively, so as to align the position of the actual center axis C**2** of the first tip **11** with the position of the axis C**3** of the shaft **92**. Notably, even after such alignment, there still exists the eccentric error Z of the actual center axis C**2** of the first tip **11** with respect to the reference center axis C**1** of the chuck **81**.

Measurement of the position of the actual center axis C**2** of the first tip **11**, etc.; i.e., the eccentric error detection step and the center axis position correction step for the first tip may be performed as follows. For example, the distal end surface (the distal end surface of the circular columnar portion) **13** of the first tip **11** is image-captured by a camera; the captured image is displayed on a monitor; and the position of the center (or the outer circumferential edge) C**2** of the distal end surface (the distal end surface of the circular columnar portion) **13** of the first tip **11** is measured by image processing. On the basis of the result of the measurement, there are detected positional errors (Ex and Ey) of the center axis C**2** in plane in the X and Y directions (error detection) with respect to a preset regular reference position (the position of the axis C**3** of the shaft **92**) where the center axis C**2** is expected to be situated at the second position P**2** (the eccentric error detection step for the first tip (the first electrode member)). When the eccentric error Z obtained on the basis of the detected amounts (errors) falls outside the tolerance range, the chuck position adjustment means **90** is driven so as to slide the slide members **91** and **93** by predetermined amounts in the X and Y directions, respectively, for fine adjustment (the center axis position correction step for the first tip (the first electrode member)). In this manner, as shown in FIG. **6**, the center axis C**2** of the actual distal end surface (the distal end surface of the circular columnar portion) of the first tip **11** is aligned with the position of the center C**3** of the shaft **92** where the center axis C**2** is expected to be situated at the stop position. In the present embodiment, a system is programmed so as to perform such fine adjustment on the basis of the above-mentioned result of measurement under computer control. The camera and the chuck position adjustment means **90** are sequentially operated in response to a signal indicative of arrival of the chuck unit **110** at the second position P**2** and are reset in response to an action of the chuck unit **110** of leaving the second position P**2** after its position is corrected by the chuck position adjustment means **90**. After the position of the chuck **81** is adjusted by the chuck position adjustment means **90**, for example, the slide members **91** and **93** are mechanically locked by a lock mechanism.

Next, after the position of the first tip **11** is corrected at the second position P**2**, the circular table **101** is rotated by 60 degrees and then stopped. By this operation, while being held in the condition of FIG. **6** in which the actual center axis C**2** of the first tip **11** is positionally corrected so as to be aligned with the axis C**3** of the shaft **92**, the chuck unit **110** is moved to a third position P**3**. In the present embodiment, at the third position P**3**, there are performed supply of the second tip (Pt tip) **21** (hereinafter, may be referred to as the second tip supply step), which corresponds to the second electrode member supply step, and temporary welding of the second tip **21** (the temporary welding step). Specifically, the second tip **21** is gripped at its outer circumferential surface by, for example, conventionally known supply means **130** including handling means **131** and transport means **133** as shown in FIG. **7**. Then, while the second tip **21** is gripped, its one end surface **23** is positioned and placed on the distal end surface of the small-diameter circular columnar portion of the first tip **11** situated at the third position P**3**. In this supply and displacement, a problem is positional alignment of the second tip **21** with the first tip **11**. In this regard, the position of the first tip **11** is corrected such that the center axis C**2** of the first tip **11** is aligned with the axis C**3** of the shaft **92** of the chuck unit **110**. Therefore, an only problem is moving accuracy in aligning the center C**2** of the second tip **21** with the axis (center) C**3** of the shaft **92**. Since the second tip **21** is moved by the supply means **130** which uses a servomechanism, etc., and thus can be disposed with involvement of almost no error. Specifically, with a high accuracy in several μm to 10 μm units, the supply and displacement of the second tip **21** does not involve the occurrence of a problematic error.

Therefore, after, as mentioned above, the second tip **21** is supplied to the first tip **11** and then positioned and disposed such that the end surfaces of the first and second tips **11** and **21** are in contact with each other, at the third position P**3**, while the distal end surface of the second tip **21** is pressed with a press pin, the outer circumferential edges of the end surfaces **13** and **23** through which the first and second tips **11** and **21** are in contact with each other may be circumferentially laser-welded. In this regard, the present embodiment involves a temporary welding step of temporarily welding the outer circumferential edges at a spot through radiation of one pulse of laser beam (see FIG. **8**). In the present embodiment, at the third position P**3**, in addition to the supply means **130** for the second tip **21**, which corresponds to the second electrode member, as shown in FIG. **7** and unillustrated pressing means (press pin) for the second tip **21**, a laser welding apparatus **201** for temporary welding is disposed (see FIG. **1**). The press pin rises after temporary welding. Before temporary welding is performed as mentioned above, preferably, the position of the second tip **21** is confirmed from two or more directions by image processing or the like.

In the present embodiment, after the temporary welding step is performed, the circular table **101** is rotated by 60 degrees and then stopped; by this operation, the chuck unit **110** in which the chuck **81** chucks the first chip **11** to which the second tip **21** is temporarily welded is moved to a fourth position P**4** in FIG. **1**. At the fourth position, the first and second tips **11** and **21** undergo regular welding. Specifically, at the fourth position P**4**, the first tip **11** and the second tip **21** are laser-welded together by circumferentially laser-welding the outer circumferential edges of the joining surfaces of the first and second tips **11** and **21**. In this laser welding (regular welding), the shaft **92** provided at the bottom of the base **120** which supports the chuck position adjustment means **90** of the chuck unit **110** is rotated substantially by one revolution in relation to the circular table **101** via unillustrated chuck unit **110** rotational-drive means. In the course of this revolution, a laser welding apparatus **301** disposed in the vicinity of the fourth position P**4** performs pulse laser welding an appropriate number of times (e.g., eight times). By this procedure, as shown in FIG. **10**B, the composite tip **31** in which the second tip **21** is laser-welded to the first tip **11** is yielded.

Although the center of rotation of the chuck unit **110** in the course of this laser welding is the axis C**3** (center) of the shaft **92**, as a result of the above-mentioned positional correction, the actual center axis C**2** of the first tip **11** is aligned with the center of the shaft **92**, i.e., the axis C**3** of the shaft. Furthermore, the second tip **21** maintains high concentricity with the first tip **11**. Therefore, even though the laser welding apparatus **301** is fixed, laser radiation distance is free of deviation. In such regular welding, as shown in FIG. **8**, it is good practice to perform welding while the second tip **21** is pressed with a second press pin **305**. Preferably, the second press pin **305** is provided in such a manner as to rotate synchronously with the rotation of the chuck unit **110** or to freely undergo synchronous rotation via a thrust bearing. For regular welding, the following practice is recommended: the laser welding apparatus **301** has correction means for correcting the laser radiation position (height); the height of the joining surfaces of the first and second tips **11** and **21** is detected with a sensor; and the laser radiation position is automatically adjusted. This is because a very small dimensional tolerance is also assigned for the height of the first tip **11**. Also, for regular welding, the following practice is recommended: as shown in FIG. **8**, for example, argon gas blowing means **307** is provided for blowing argon gas toward a weld zone, and in the course of welding, argon gas is blown to prevent adhesion of welding spatters to the surface of the composite tip **31**.

As mentioned above, regular welding is performed at the fourth position P**4**, thereby manufacturing the composite tip **31**. In the present embodiment, subsequently, the circular table **101** is rotated by 60 degrees and then stopped at a fifth position P**5**. At the fifth position P**5**, the composite tip **31** undergoes appearance inspection effected by image inspection processing in order to inspect its surface including the weld zone for adhesion of welding spatters and existence of welding sag. Also, in this inspection, similar to the practice at the fourth position P**4**, the shaft **92** of the chuck unit **110** may be rotated for appearance inspection of the composite tip **31**. In the inspection, through rotation of the composite tip **31**, welding spatters and welding sag can be readily detected as protrusions (convexes).

In the present embodiment, after the image inspection processing, the circular table **101** is rotated by 60 degrees to send the chuck unit **110** to an eject position at a sixth position P**6**. At the sixth position P**6**, the chuck **81** is opened to eject the composite tip **31** which has undergone regular welding, whereby the welded composite tip **31** is delivered. Preferably, in ejection, the composite tips **31** are ejected while being classified according to acceptance and rejection on the basis of judgment of acceptance and rejection (non-defective and defective) in the appearance inspection at the position P**5**. The chuck unit **110** which has released the composite tip **31** is sent to the start position of the process; i.e., the first position P**1**, by rotating the circular table **101** by 60 degrees. Notably, it is good practice for the chuck unit **110** to be reset again after the appearance inspection and before transmission to the start position such that the reference center axis C**1** of the chuck **81** is aligned with the shaft **92** of the chuck unit **110** by driving the chuck position adjustment means **90**. Subsequently, the above-mentioned steps which start from supply of the first tip **11** are repeated, thereby manufacturing the composite tips **31**, which correspond to the electrode composites, one after another.

As mentioned above, according to the manufacturing method of the present embodiment, after the first tip **11**, which corresponds to the first electrode member, is held by the chuck **81**, even though the actual center axis C**2** of the first tip **11** is eccentric in excess of tolerance to the reference center axis C**1** of the chuck **81** and to the axis of the shaft **92**, at the second position P**2**, before the second tip **21**, which corresponds to the second electrode member, is supplied and then positioned and disposed, the position of the first tip **11** is corrected so as to be aligned with the position of the shaft **92**. That is, the manufacturing method has the eccentric error detection step which comes after the first tip holding step (first electrode member holding step) and before the second tip supply step (second electrode member supply step). The eccentric error detection step is adapted to detect an eccentric error between the position of the actual center axis C**2** of the first tip **11** and the shaft **92** of the base **120** rotatably supporting the chuck **81** of the chuck unit. When the eccentric error detected by the eccentric error detection step falls outside the tolerance range subsequent to the eccentric error detection step, the center axis position correction step corrects the position of the actual center axis C**2** of the first tip so as to align the actual center axis C**2** of the first tip with the axis C**3** of the shaft **92** of the base **120**. Thus, at the subsequent third position P**3**, when the second tip **21** is supplied to the positioned first tip **11**, the first and second tips **11** and **21** can be disposed concentric with the shaft **92** with high coaxiality. Therefore, subsequently, when the first and second tips **11** and **21** are welded, while the chuck unit **110** is rotated about the axis C**3** of the shaft **92**, the composite tip **31** having high coaxiality can be efficiently yielded.

That is, the above-mentioned manufacturing method does not employ the following aligning method: after the second tip **21**, which corresponds to the second electrode member, is supplied and then positioned and disposed on the first tip **11**, which corresponds to the first electrode member, held by the chuck **81** (after the second tip **21** supply step), coaxiality between the first and second tips **11** and **21** is measured, and if the measured coaxiality involves an error which falls outside tolerance, the coaxiality (eccentric error) of the second tip **21** with respect to the first tip **11** is adjusted. Therefore, according to the present invention, the joining surfaces (the end surfaces of the first and second tips in contact with each other) **13** and **23** do not rub each other and thus are free from scratching.

Furthermore, in the present embodiment, as described above, the six chuck units **110** are provided on the circular table **101** in such a manner as to be disposed at equal angular intervals on the imaginary circle **103** whose center is concentric with the rotational center **100** of the circular table **101**; at the positions P**1** to P**6** located at 60-degree intervals, there are performed the step of supplying the first tip **11**, which corresponds to the first electrode member, to the chuck **81** and holding the first tip **11** by the chuck **81**, the eccentric error detection step and the center axis position correction step for the first tip **11**, the step of supplying the second tip **21**, which corresponds to the second electrode member, and the temporary welding step, the regular welding step, the image inspection step, and the step of ejecting the welded composite tip **31**; by this procedure, while the circular table **101** is rotated by one revolution, the composite tip is manufactured and then ejected. That is, since these steps are carried out at the corresponding stop positions, residence time at the individual stop positions is reduced; therefore, efficiency in manufacturing the composite tip **31**, which corresponds to the electrode composite, can be markedly enhanced.

In the above-described embodiment, detecting the position of the first tip **11** (eccentric error detection step), which corresponds to the first electrode member, and correcting the position (center axis position correction step) are performed at the same position (second position P**2**) in the course of rotation (in the course of revolution) of the circular table **101**. However, these steps may be performed at different positions in the course of revolution, so long as the steps are performed before supply of the second tip **21**, which corresponds to the second electrode member. Therefore, in the above-described embodiment, the detecting step and the correcting step may be performed as follows: after detection of an eccentric error between the position of the actual center axis C**2** of the first tip **11**, which corresponds to the first electrode member, and the axis C**3** of the shaft **92** of the chuck unit **110** (after the eccentric error detection step), the circular table **101** is rotated again so as to move the chuck unit **110** by a predetermined amount, and then stopped. Then, at the different stop position after the detection step, if the eccentric error falls outside the tolerance range, the position of the chuck **81** is corrected (center axis position correction step) as mentioned above; i.e., the position of the actual center axis C**2** of the first tip **11**, which corresponds to the first electrode member, is aligned with the position of the shaft **92**. In this manner, this positional correction (center axis position correction step) may be performed at a different position, so long as the correction step is performed before the second tip supply step, which corresponds to the second electrode member supply step.

Also, the above embodiment is described while mentioning the case where the steps are performed at the six positions. However, revolution may be stopped at 45-degree intervals so as to perform the steps at eight positions as follows: five of the above-mentioned steps; i.e., the step of supplying the first tip **11** to the chuck **81** (first electrode member holding step), the eccentric error detection step for the first tip **11**, the center axis position correction step for the first tip **11**, the second tip supply step (second electrode member supply step), and the temporary welding step, are separately performed at the first to fifth positions, and the remaining three steps; i.e., the regular welding step, the appearance inspection step, and the ejection step, are performed at the sixth to eighth positions. The appearance inspection step may be performed after the ejection step of ejecting the composite tip from the regular welding step, and ejection and regular welding may be performed at the same position.

Furthermore, the above embodiment is described while mentioning the case where, before the outer circumferential edges of the end surfaces of the first and second tips, which correspond to the first and second electrode members, are laser-welded (undergo regular welding), temporary welding is performed at the preceding step (second electrode member supply step); subsequently, at the advanced position P**4**, regular welding is performed. However, without performing such temporary welding, at the fourth position P**4** in the above-mentioned embodiment, temporary welding and regular welding may be performed simultaneously, or regular welding may be directly performed. Furthermore, regular welding can be performed by use of, for example, two laser welding apparatus. In such a case, the chuck unit **110** can be rotated about the shaft **92** half a revolution or less.

The present invention is not limited to the above embodiment, but may be embodied in an appropriately modified form without departing from the gist of the invention. For example, the revolvingly moving means for the chuck units is described while mentioning a rotary table. However, the revolvingly moving means is not limited thereto. In the case where the electrode composite to be manufactured is the above-mentioned composite tip, the electrode composite may be adapted to form the center electrode or the ground electrode of the spark plug. By configuring a center electrode **71** or a ground electrode **61** of the spark plug **41** shown in FIG. **11** by use of the thus-manufactured composite tip **31**, a high-performance spark plug can be yielded. That is, for example, the ground electrode is formed by welding the composite tip **31**, which corresponds to the electrode composite, to a ground electrode body **60** via the first tip **11** of the composite tip **31** such that the second tip of the composite tip **31** is located on a side toward the spark gap.

The above embodiment is described while mentioning the composite tip **31** shown in FIG. **10**B as the electrode composite to be manufactured. However, as is apparent from the above description, the electrode composite to be manufactured in the present invention is not limited to the composite tip **31**. That is, the electrode composite may be the entire center electrode **71** of the spark plug **41** shown in FIG. **11** such that the first electrode member is a center electrode body **70** and such that the second electrode member is an electrode tip **77** welded to the forward end of the center electrode body **70**. This is for the following reason: even in manufacture of such a center electrode **71**, the above-mentioned method can be applied; specifically, as shown in FIG. **9**, by use of an apparatus similar to that mentioned above and the chuck unit **110**, the center electrode body **70**, which is a stem member, is chucked; the electrode tip (which corresponds to the noble metal tip in the above-described embodiment) **77** is supplied and then positioned and disposed on a forward end **72** of the center electrode body **70**; and steps similar to those mentioned above are carried out.

That is, in the case where the electrode composite is the center electrode **71** as mentioned above, as shown in FIG. **9**, the manufacturing apparatus mentioned in the description of the above embodiment may be modified such that the chuck **81** of the chuck unit **110** and the claws **83** of the chuck **81** have shapes and structures capable of appropriately holding the center electrode body **70**, which corresponds to the first electrode member, shown in FIG. **9**. The manufacturing apparatus is also modified to allow the following: after the center electrode body **70** is held by the claws **83** of the chuck **81**, the electrode tip **77**, which corresponds to the second electrode member, is supplied and disposed such that its end surface is concentrically in contact with the end surface (forward end surface) **72** of the center electrode body **70**. In this manner, the first and second electrode members of the electrode composite differ from those of the composite tip in the above embodiment; however, apparently, similar effects are yielded by undergoing steps similar to those in the above embodiment.

In the case where the electrode composite is the center electrode **71**, the center electrode body **70**, which corresponds to the first electrode member, of the center electrode **71** is relatively thick and long in contrast to the first tip **11** in the above embodiment. Specifically, the center electrode body **70** has, for example, as shown in FIG. **9**, a circular stem (a circular stem of a fixed diameter) **73** as a base body, and a circular flange **76**, which is located toward a rear end (a lower end in FIG. **9**) **75** of the circular stem **73**, is coaxial with the circular stem **73**, and projects outwardly from the circular stem **73**. In such a case, as shown in FIG. **9**, the chuck **81** may be configured as follows: when driven, the chuck **81** can hold the center electrode body **70** at an intermediate portion (outer circumferential surface) of the circular stem **73** located forward of the circular flange **76**. The chuck **81** in FIG. **9** is formed such that its claws **83** can accommodate a rear-end portion, including the circular flange **76**, of the circular stem **73** of the center electrode body **70**. In FIG. **9**, the electrode tip **77**, which corresponds to the second electrode member, assumes the form of a circular columnar member having an outside diameter slightly smaller than that of the forward end **72** of the center electrode body **70**, which corresponds to the first electrode member. Thus, after the electrode tip **77** is supplied and disposed such that its end surface comes into coaxial (concentric) contact with the forward end (forward end surface) **72** of the center electrode body **70**, the electrode tip **77** is welded along the outer circumference of its joining surface.

In the above embodiments, the electrode composites to be manufactured are the composite tip and the center electrode. However, the electrode composite of the present invention is not limited thereto, but can be widely applied to electrode composites for forming electrodes of spark plugs. That is, the electrode composite according to the present invention can be widely applied to electrode composites for forming electrodes of spark plugs, the electrode composites each being formed by laser-welding the first electrode member and the second electrode member. This is for the following reason: in manufacture of these electrode composites, by use of an apparatus similar to that mentioned above, the first electrode member is chucked; the second electrode member is supplied and then positioned and disposed on the end of the chucked first electrode member; and steps similar to those mentioned above are carried out; therefore, effects similar to those mentioned above are yielded by undergoing steps similar to those mentioned above. The electrode composite may be a component member of the center electrode, for example, a portion of the center electrode rather than the entire center electrode. In this case, by welding the first electrode member and the second electrode member, the portion of the center electrode (e.g., a portion, including the forward end, of the center electrode rather than the entire center electrode) is formed.

Embodiments 1 to 3 of the invention of a method of manufacturing an electrode composite are disclosed below. In embodiments 1 to 3, the electrode composite to be manufactured is the composite tip; the first electrode member is the first tip (tip body); and the second electrode member is the second tip (noble metal tip). However, even in embodiments 1 to 3, the electrode composite can be applied to the center electrode, etc., so long as the electrode composite is adapted to form an electrode of a spark plug. That is, in embodiments 1 to 3, the composite tip can be replaced with the electrode composite (e.g., the center electrode); the first tip can be replaced with the first electrode member (e.g., the center electrode body); and the second tip can be replaced with the second electrode member (e.g., an electrode tip in the form of a noble metal tip).

Embodiment 1

In accordance with a first embodiment of the present invention, there is provided a method of manufacturing a composite tip for forming an electrode of a spark plug, the composite tip being formed by welding a first tip corresponding to a tip body, and a second tip corresponding to a noble metal tip, the method comprising a step of positioning such that end surfaces of the first and second tips come into contact with each other, and a laser welding step of welding outer circumferential edges of the end surfaces through which the first tip and the second tip are in contact with each other,

the method being characterized in that:

a manufacturing apparatus used in the method has a plurality of chuck units, each including a chuck having a plurality of chuck claws capable of holding the first tip, chuck position adjustment means capable of adjusting the position of a reference center axis of the chuck, and a pedestal for supporting the chuck position adjustment means, and the pedestal of each of the chuck units has a shaft being coaxial with the reference center axis of the chuck or being able to be coaxial with the reference center axis of the chuck through adjustment by the chuck position adjustment means;

the chuck units are disposed via the shafts on a revolvingly moving means at predetermined positions, the revolvingly moving means revolving on a predetermined path and being controlled so as to stop at least at positions where the steps are performed, and the chuck units are configured to be rotatable about the axes of the shafts at least at a position where the laser welding step is performed;

after the revolvingly moving means is driven, the first tip is supplied to and held by the chuck of the chuck unit situated at a process start position; subsequently, the revolvingly moving means is driven to move, by a predetermined amount, the chuck unit which holds the first tip, and then to stop the chuck unit;

at the stop position, the position of the actual center axis of the first tip held by the chuck is measured by image processing, and an eccentric error is detected between the position of the actual center axis of the first tip and the shaft of the chuck unit;

when the eccentric error falls outside a tolerance range, the chuck position adjustment means is driven to correct the position of the chuck for aligning the position of the actual center axis of the first tip with the position of the shaft; subsequently, the revolvingly moving means is driven to move the chuck unit by a predetermined amount and then to stop the chuck unit;

at the stop position, the second tip is supplied and positioned such that the end surfaces of the first and second tips come into contact with each other; and

subsequently, while the chuck unit in which the second tip is positioned and disposed on the first tip is rotated about the axis of the shaft, the outer circumferential edges of the end surfaces through which the first tip and the second tip are in contact with each other are laser-welded.

Embodiment 2

In accordance with a second embodiment of the present invention, there is provided a method of manufacturing a composite tip for forming an electrode of a spark plug as described above with respect to embodiment 1, further characterized in that,

in place of the following limitation:

"the position of the actual center axis of the first tip held by the chuck is measured by image processing, and an eccentric error is detected between the position of the actual center axis of the first tip and the shaft of the chuck unit;

when the eccentric error falls outside a tolerance range, the chuck position adjustment means is driven to correct the position of the chuck for aligning the position of the actual center axis of the first tip with the position of the shaft; subsequently, the revolvingly moving means is driven to move the chuck unit by a predetermined amount and then to stop the chuck unit;"

the position of the actual center axis of the first tip held by the chuck is measured by image processing, and an eccentric error is detected between the position of the actual center axis of the first tip and the shaft of the chuck unit, and subsequently, the revolvingly moving means is driven to move the chuck unit by a predetermined amount and then to stop the chuck unit, and

at the stop position, when the eccentric error falls outside the tolerance range, the chuck position adjustment means is driven to correct the position of the chuck for aligning the position of the actual center axis of the first tip with the position of the shaft; subsequently, the revolvingly moving means is driven to move the chuck unit by a predetermined amount and then to stop the chuck unit.

Embodiment 3

In accordance with a third embodiment of the present invention, there is provided a method of manufacturing a composite tip for forming an electrode of a spark plug as described in embodiments 1 or 2, further characterized in that,

in place of

"the second tip is supplied and positioned such that the end surfaces of the first and second tips come into contact with each other; and

subsequently, while the chuck unit in which the second tip is positioned and disposed on the first tip is rotated about the axis of the shaft, the outer circumferential edges of the end surfaces through which the first tip and the second tip are in contact with each other are laser-welded,"

the second tip is supplied and positioned such that the end surfaces of the first and second tips come into contact with each other;

subsequently, the outer circumferential edges of the end surfaces through which the first tip and the second tip are in contact with each other are temporarily welded by laser welding; subsequently, the revolvingly moving means is driven to move the chuck unit by a predetermined amount and then to stop the chuck unit; and

at the stop position, while the chuck unit is rotated about the axis of the shaft, the outer circumferential edges of the end surfaces through which the first tip and the second tip are in contact with each other are laser-welded.

Embodiment 4

In accordance with a fourth embodiment of the present invention, there is provided a method of manufacturing a composite tip for forming an electrode of a spark plug according to any one of embodiments 1 to 3 mentioned above, further characterized in that the revolvingly moving means is configured to intermittently move the chuck units by predetermined amounts at equal angular intervals on and along a fixed circular path.

Having described the invention, the following is claimed:

1. A method of manufacturing an electrode composite for forming an electrode of a spark plug, the electrode composite being formed by laser-welding a first electrode member and a second electrode member together,

the method comprising the steps of:

a first electrode member holding step of holding the first electrode member by a chuck of a chuck unit;

an eccentric error detection step to detect an eccentric error between a position of an actual center axis of the first electrode member and a shaft of a base rotatably supporting the chuck of the chuck unit;

a center axis position correction step of correcting the position of the actual center axis of the first electrode member when the eccentric error detected in the eccentric error detection step falls outside a tolerance range subsequent to the eccentric error detection step, said center axis position correcting step aligning the actual center axis of the first electrode member with an axis of the shaft of the base;

a second electrode member supply step of supplying the second electrode member such that an end surface of the second electrode member comes into contact with an end surface of the first electrode member; and

a laser welding step of welding outer circumferential edges of the end surfaces through which the first electrode member and the second electrode member are in contact with each other.

2. A method of manufacturing an electrode composite for forming an electrode of a spark plug according to claim **1**, further comprising a temporary welding step coming after the second electrode member supply step and before the laser welding step, said temporary welding step adapted to temporarily weld the outer circumferential edges of the end surfaces through which the first electrode member and the second electrode member are in contact with each other.

3. A method of manufacturing an electrode composite for forming an electrode of a spark plug according to claim **1** or **2**, characterized in that:

a plurality of the chuck units are disposed on revolvingly moving means so as to sequentially move in association with revolution of the revolvingly moving means, and

the eccentric error detection step and the center axis position correction step are performed at the same position in the course of revolution.

4. A method of manufacturing an electrode composite for forming an electrode of a spark plug according to claims **1** or **2**, characterized in that:

a plurality of the chuck units are disposed on revolvingly moving means so as to sequentially move in association with revolution of the revolvingly moving means, and

the first electrode member holding step and the eccentric error detection step are performed at different positions in the course of revolution.

5. A method of manufacturing a spark plug which has an insulator having an axial bore in a direction of an axis, a center electrode disposed in a forward end portion of the axial bore, a metallic shell circumferentially surrounding the insulator, and a ground electrode whose one end is joined to the metallic shell and whose other end faces a forward end of the center electrode, and in which the center electrode or the ground electrode is an electrode composite formed by joining a first electrode member and a second electrode member together, or has the electrode composite joined thereto,

the method being characterized in that the electrode composite is manufactured by a manufacturing method according to claims **1** or **2**.

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